MDE Product Development Team
March 2013 2nd Quarterly Report
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(Compiled and edited by S. Weygandt and B. Johnson)

Executive Summary

Task 1: Improve turbulence guidance from NWP forecasts

- Strong progress on testing and evaluation of RAP data assimilation and model changes within the RAP real-time parallel and retrospective cycles including:
  -- use of global ensemble information within GSI-based hybrid assimilation procedure for RAP
  -- improved 9 level version of Smirnova Land Surface Model
  -- evaluation and decision to use specially adapted version of MYNN BL scheme in place of current MYJ
  -- improvements to RAP radar-based hydrometeor building and clearing
- RAP version 2 upgrade at GSD complete and continuing to yield improved upper-air wind/temp/RH forecasts over RAP-NCEP. The same is true for surface moisture and precipitation forecasts.
- ESRL use of hybrid/ensemble data assimilation (with 80-member GFS global ensemble) to specify background error covariance information for real-time parallel RAP marks major step forward, significantly improves RAPv2
- Upgraded RAP version 2 code nearly ready for transfer to NCEP for pre-implementation testing and eventual implementation by NCO (now proposed for early 2014 after NCEP implementation moratorium is lifted).
- Three real-time parallel RAP cycles (with extensive verification of each) running on Zeus NOAA research supercomputer located in Fairmont, WV to evaluate further likely enhancements to RAP data assimilation / model system.
- Ongoing evaluation of refined cloud analysis procedure [with selective use of Effective Cloud Amount ECA) parameter provided by the CLAVR-x (Clouds from AVHRR Extended) satellite data.
- NCEP making progress on NAM and NAM-nest
- Operational RAP including RAP GSI component successfully ported to new WCOSS machine
- Discussions with EMC, NSSL, and CAPS personnel at Norman Warn-on-Forecast (WoF) meeting on assimilation strategies and use of RAP/HRRR and their ensembles for WoF.

Task 2: Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

- Frozen RAPv2 / HRRR system obtained with numerous enhancements leading to significant improvements for HRRR forecasts of convection and other phenomena (intensive testing and evaluation of numerous RAPv2 and HRRR model and data assimilation components produced these results)
- Key HRRR model improvements: update to WRF-ARW version 3.4.1, MYJ → MYNN PBL, Dudhia → Goddard shortwave radiation, new 9 layer LSM with improvements to surface roughness.
- Key HRRR data assimilation improvements: Direct 3-km radar reflectivity assimilation during 1-h pre-forecast spin-up, application of GSI for HRRR domain at end of pre-forecast spin-up.
- GSD continues to run two real-time experimental HRRRs (a primary one - PRIM on JET and a developmental one – DEV on Zeus, both with real-time verification.
- Ongoing transfer of real-time HRRR fields from JET to NCEP Central Operation (NCO) for distribution
- Real-time experimental HRRR-based RTMA 2D surface analysis and RUA cloud analysis running on Zeus with graphics (including “analysis – background” plots) available on web and quantitative “fit to observations” verification.

Task 3: Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

- Extensive test and evaluation during the quarter produces decision on physics configuration for RAPv2
- 9-level RUC land-surface model: improvement in surface wind forecast and 2-m temperature forecast
- GSD/Olson version of MYNN boundary-layer scheme: improvement in low-level wind forecasts
- Continue use of Grell G3 parameterization of deep convection from WRFv3.2.1.
- Integration of bug correction into RAP/ WRF regarding lack of radiation effects from snow mixing ratio in atmosphere, which has been contributing to a daytime warm bias in the RAP and HRRR at the surface.
- NCAR/RAL making excellent progress on aerosol-aware microphysics

Task 4: Develop convection-ATM-specific improvements to guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA

- Finalized RAP and HRRR change package for 2013 warm season with numerous enhancements to RAP and HRRR model and data assimilation system resulting in significant improvements to HRRR forecasts.
- HRRR radar assimilation package added with 3-km, 15-min cycling, one-hour pre-forecast radar assimilation period and GSI assimilation of conventional observations on HRRR domain.
- Significant work completed to adapt / optimize new 2013 RAP/HRRR system for Zeus and jet supercomputers, leading to reduction in forecast run time.
- Significant progress toward independent Zeus and Jet RAPv2/HRRR systems to enable full failover capability between the two computer systems.
- Initial tests of a fully cycled 3-km assimilation using GSI for the HRRR and 3D 3-km application for the Rapidly Updated Analysis (RUA).
- Multiple presentations on latest HRRR results at AMS Aviation, Range, and Aerospace Meteorology (ARAM) Conference in January.

Task 1: Improve turbulence guidance from NWP forecasts

Improving turbulence forecast quality involves efforts to improve initial conditions for the RAP and NAM (and HRRR and NAM nests) and to improve the models (WRF-Advanced Research WRF (ARW)-RAP and NOAA Environmental Modeling System (NEMS)- Nonhydrostatic Multi-scale Model – B (NMMB)).

Tasks will include:

- Continuing evaluation of RAPv2 toward early 2014 implementation at NCEP, incorporating changes developed in 2012 and early 2013.
- Collaborating on developing & testing best approaches for use of hybrid/EnKF/3DVAR within common GSI coding structure.
- Collaborating on developing and testing physics schemes between WRF and NEMS' physics layer.
- Negotiating Data Mining List priorities with NCEP Central Operations and external points of contact associated with the most desirable new sources of observations. (NCEP and ESRL)
- Continuing final testing of RAPv3, including initialization of the HRRR.

ESRL

Regarding the NCEP RAP

The operational RAP at NCEP continues to run without any technical problems although with a single post-processing glitch during the month. The RAP continues to show improved reliability over the previous RUC at NCEP. On 3 March a UniPost crash occurred, due to a spurious decrease in height with decreasing pressure in a grid column on one of the lateral boundaries. A patch was made that has avoided such problems since. An improved specification of height on the lateral boundaries is under investigation.

Geoff Manikin reported in early February that the NCEP RAP had been converted to run on the new WCOSS computer. Geoff cites work by Ming Hu of GSD as critical to this process. Next will come testing of a parallel cycle on the WCOSS machine. Once this is successful. Geoff Manikin is prepared to begin accepting updated RAPv2 code from GSD for testing on the WCOSS computer. We now anticipate that this may be possible by late spring or early summer. With this quarter's completion of a code package upgrade for a RAPv2 configuration that will support the HRRR for the 2013 summer convection season, we are very close to a final configuration for the RAPv2 code that will go to NCEP for implementation in 2014.

Regarding the ESRL RAP

During the quarter ESRL/GSD efforts were almost exclusively directed toward further development, testing and evaluation, and staged implementation in GSD real-time cycles of RAP and HRRR upgrades. These upgrades are extensive, touching every major component of the RAP and HRRR. This continues as truly a team effort, involving to one extent or another most AMB personnel, but with Curtis Alexander, Ming Hu, Tanya Smirnova, Joe Olson, Eric James and David Dowell being the key players. Critical also is the availability of the Zeus supercomputer resource, on which we continue to run 3 RAP development cycles in addition to the GSD RAP-primary cycle on Jet. We use the real-time RAP-development cycles on Zeus to do controlled comparisons of numerous changes to both analysis and model. Testing on summer retrospective periods is also necessary to gauge the impact of these changes under summertime conditions. As a larger group we meet typically at least once a week for several hours of careful evaluation and identification of issues, and to configure real-time and retrospective runs to address these issues. In addition, numerous impromptu meetings occur every day. Crucial in this process is the facile AMB interactive verification system.

A major last obstacle proved to be porting the code tested on Zeus to the slightly different computing environment on Jet where the RAP-primary and HRRR are run, but where no RAP or HRRR development work is allowed. Night and weekend effort by Ming Hu, Curtis Alexander and Tanya Smirnova to discover and fix complex WRF memory allocation issues now allow the RAP-primary and HRRR with the latest code modifications to run smoothly on Jet.

At this writing the summer 2013 RAP configuration is set. Selected changes are reviewed below. A complete list of changes can be found at **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2013.pdf** .

Analysis

- Replacement of the current purely 3DVAR analysis option in the Gridpoint Statistical Interpolation (GSI) analysis by GSI's new hybrid EnKF-variational option, together with use of 6-9h forecast grids from the 80-member GFS ensemble that are part of the highly successful global implementation of the GSI hybrid. Performance of this new assimilation technique in the Zeus RAP-dev3 cycle has produced a dramatic improvement in RAP performance and this is now running in all the RAP development cycles and the real-time GSD primary RAP. We are working with NCEP to improve RAP reliability on Zeus (making it less dependent on Jet availability) by transferring these files directly from NCEP to Zeus.
- Revised the soil temperature and moisture adjustment introduced in late 2011 to be symmetric with respect to both warming/drying and cooling/moistening the soil conditions. The magnitude of the adjustments has also been increased. The intent of this procedure is to gently moisten and cool (or dry and warm) the soil when there is evidence from comparing METAR 2-m observed temperature and dew point with the RAP 1-h forecast that the soil is too dry and warm (or moist and cool). This adjustment is only done in daytime when the RAP 1-h forecast produces a surface-based mixed layer.
- Changed the cycled snow cover fields in the RAP through modifications in building and/or removal of snow cover in the 00 UTC cycle based upon the Interactive Multisensor Snow and Ice Mapping System (IMS) snow cover analysis. Surface temperature dependence has been removed from the snow trimming analysis. Snow building capability is enabled when surface temperature T < 278 K.

Model (more on the first two bullets under Task 3)

- Replace WRFv3.3.1 with v3.4.1 (released Aug. 2012), but keep the Grell G3 deep convection scheme from v3.2.
- Replace the MYJ planetary boundary and surface layer schemes by the GSD / Olson version of MYNN.
- Use of the 9-level RUC LSM that has been in real-time testing since fall 2012, and has been reported on in previous MDE reports to give generally improved temperature forecasts.
- Use of increased surface roughness over urban and forested areas as well as seasonally dependent surface roughness over agricultural areas and use of a leaf-area index that is a function of land-use type and seasonally dependent vegetation fraction.

Intensive evaluation of the new GSI cloud analysis enhancements including Effective Cloud Amount (ECA) from the improved CLAVR-x (Clouds from AVHRR [Advanced Very High Resolution Radiometer] Extended) data from NESDIS continued during the quarter. However, we have decided to hold off for the time being on implementation of this, pending more evaluation of thresholds to use in determining areas of partial cloudiness (equivalent to METAR SCT or BKN sky cover) and other considerations implied in switching to the CLAVR data.

Haidao Lin continued his work on obtaining improved results for AIRS satellite radiance assimilation. Also, GSD assimilation scientists participated in discussions with EMC, NSSL, and CAPS personnel in Norman, OK at a Warn-on-Forecast (WoF) workshop. Ideas and strategies for data assimilation to address short-range high impact weather forecast needs were discussed, including plans for use of the RAP/HRRR and their ensembles.

Other activities, some noted more fully under other tasks, also were undertaken:

- The NCAR WRF developers made a first beta release of WRFv3.5 available for testing by friendly developers in late January and a second release in early March. This includes a number of contributions by GSD developers: the latest version of the RUC LSM (Smirnova), the Grell-Freitas deep and shallow convection, the MYNN PBL and surface-layer schemes updated through late December (Olson) and the current version of the RAP digital filter initialization (Peckham and Smirnova). Tanya Smirnova has made some preliminary non-cycled runs with this release.
- Continued evaluation of the Earth Networks, Inc. lightning data for use as a possible alternative to the Vaisala GLD360 lightning product.
- Retrospective testing of satellite radiance bias corrections and choice of background error (Task 5).
- Retrospective testing for both RAP and HRRR of the impacts of proprietary in situ tower wind data and other special data continues under funding from the DOE Wind Forecast Improvement Project.

NCEP

Work to convert the Rapid Refresh codes and scripts to run on the new WCOSS supercomputer was completed during this quarter. The codes were turned over to NCO in February, and NCO got the system running in real-time parallel mode in March. A preliminary basic timing test for the High-Resolution Rapid Refresh [HRRR] was performed. (Geoff Manikin)

The SREF codes were turned over to NCO for transition this quarter as were the codes for NARRE-TL, which is part of the RAP system in operations. NCO started a production parallel of NARRE-TL and ran a test case; the results were confirmed to match those of CCS against the same input data. The transition of NARRE-TL plot generation scripts to WCOSS was also completed. Per the request of WFO Caribou, Maine, the eastern extent covered by the NARRE-TL CONUS webpage at **http://www.emc.ncep.noaa.gov/mmb/SREF_avia/FCST/NARRE/web_site/html/icing.html** was extended to cover most of the maritime provinces of Canada. The surface cooling computation in the fog diagnostic code was modified in the ensemble product generator and the modification was verified against several fog events in east coast, showing its improvement in fog detection rate. (BinBin Zhou and Jun Du)

Work continues to add a GLERL-type analysis for lake winds to the RTMA-GSI; pseudo-wind observations created from adjusting the nearby land observations to the water conditions are now being successfully added to the RTMA observation file. Work is underway to add to the GSI the capability to analyze the lake winds separately from the land winds. (Manuel Pondeca, Steve Levine)

A bug in the WCOSS level2-radar data decoder was found and fixed. The decoder couldn't properly decode dual-polarity data when the data volume is incomplete. The bug was fixed by checking the dual-polarity index at each elevation angle, and marking the whole data volume as dual-polarity if it is marked at any elevation angle. This fix is under parallel test. Tests of reflectivity assimilation continue in a real time parallel. A few script and code modifications were made following the changes of the NAM parallel. Current aggregated test results show improved fields at the end of the data assimilation and especially precipitation scores which were improved significantly. The improvement (although smaller in magnitude) was also found during the free forecast. Assistance was given to GSD in transitioning the RAP radar data pre-processing package to WCOSS. The cloud analysis package was completely transitioned to Zeus, and testing begun. (Shun Liu)

Preparations continue for using the data from new satellites in the GSI. The error characters, data thinning and quality control of the observations from various satellites had to be defined independently. Error corrections were made to the scripts and analysis code to ensure an improved analysis package for the future implementation. The new features for this package included hybrid variational-ensemble analysis with ensemble perturbations generated from the global EnKF system (now being used in RAPv2), GOES15 radiances, variational QC scheme inside GSI, Meteosat 10, satellite wind subtypes with different data thinning, radiosonde level enhancement in GSI, mesonet wind observation reject list (from RTMA), new VAD wind profiles from Doppler radars, and GPS bending angle observations. A great deal of effort was put into moving the GSI package to the new WCOSS computer. (Wan-Shu Wu)

CAPS

During this quarter, CAPS mainly worked on updating and testing the dual-resolution hybrid DA capabilities for RAP, using 40/13 dual resolutions. The hybrid system uses the well tuned 40km EnKF system to provide flow-dependent covariances, and short-range forecasting results are compared with those from GSI running at 13 km grid spacing (labeled GSI13KM), and 13-km forecasts lunched from interpolated 40km EnKF mean analyses (labeled EnKF_I13KM). Earlier problems with the hybrid system when ensemble covariance was used at 100% were fixed.

Full tests over a 9-day period similar to earlier EnKF and single-resolution hybrid tests were performed, using 40/13km dual resolutions, and 0% and 50% static covariance, respectively (named HybridDual00 and HybridDual05). The averaged 3-hour forecast RMSEs verified against sounding data (Fig. 1) show that using 50% ensemble and 50% static covariance in HybridDual05, the forecast errors are comparable or slightly larger than those of EnKF_I13KM, which is the best among the 4 experiments. GSI13KM generally performs the worst, except for RH at the mid and upper levels, where HybridDual05, i.e., the hybrid with 100% ensemble covariance,

performs the worst. While the hybrid system appears to be functional, further testing and tuning (with, e.g., localization) are still needed to obtain better results.

During this quarter, CAPS submitted a paper to Monthly Weather Review documenting the 40-km EnKF testing results. The paper is accepted subjecting to mostly minor revisions.

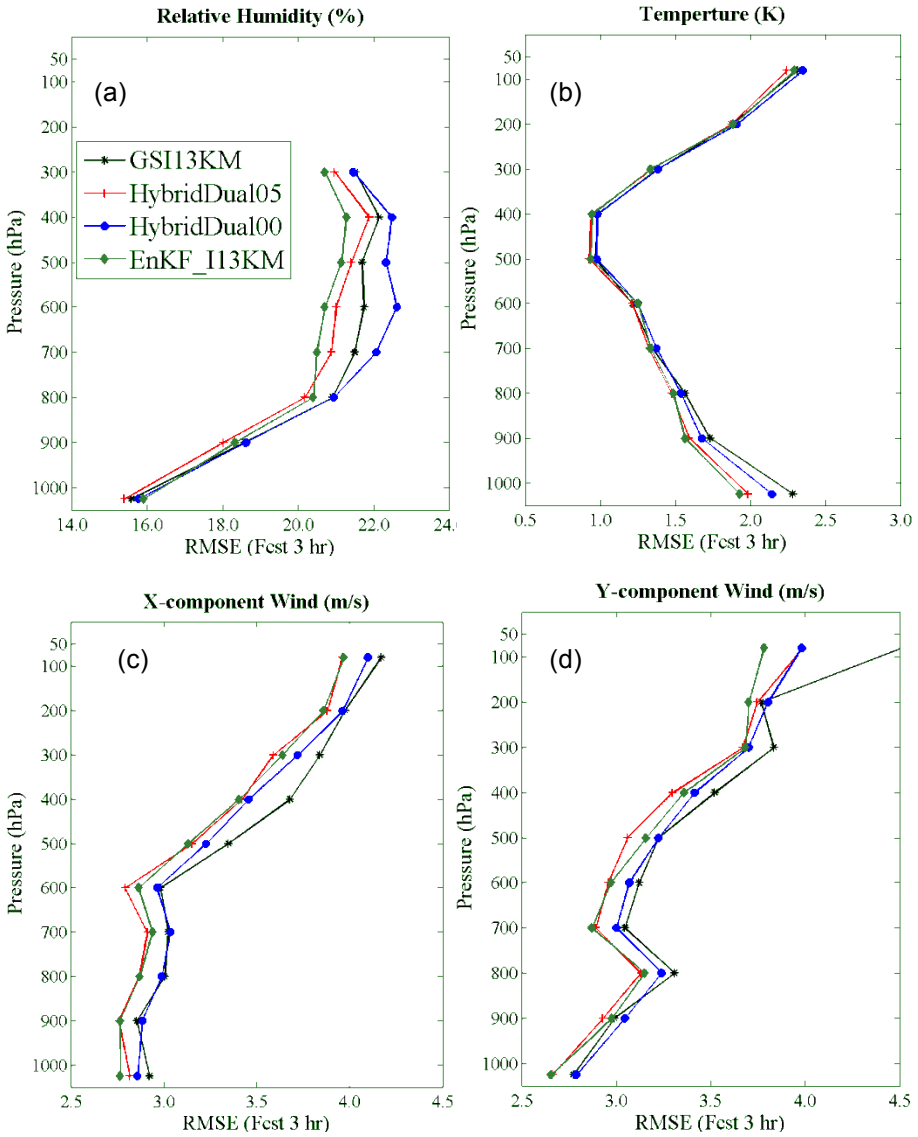

Fig. 1. Vertical profiles of 3-h forecast RMSEs verified against sounding data for (a) RH (b) T (c) U and (d) V.

Additional information on RAP-related tasks

ESRL

GSD continues to make pgrb and bgrb files from the ESRL/GSD RAP-primary (RAPv2) real-time 1-h cycle available from its FTP site for users in NWS and other labs).

NCEP

NCEP maintained real-time availability of SAV and AHP guidance to all vendors from the operational hourly RAP on pressure surfaces via the NWS Family of Services (FOS) data feed and via the FAA Bulk Weather Data Telecommunications Gateway (FBWDTG). (EMC&NCO)

NCEP maintained real-time availability of full resolution gridded data from the operational RAP runs via anonymous ftp access via the NCEP server site at **ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/rap/prod/** and at the NWS/OPS site at **ftp://tgftp.nws.noaa.gov/SL.us008001/ST.opnl/** in hourly directories named MT.rap_CY.00 through MT.rap_CY.23. This includes hourly BUFR soundings and output grids, which undergo no interpolation. Both sites now contain only grids in GRIB2 format **http://www.nco.ncep.noaa.gov/pmb/docs/GRIB1_to_GRIB2.shtml.** Gridded RAP and NARRE[-TL] fields are available on **NOMADS** for the CONUS domain on 13 km grid #130 and the Alaska domain on 11.25 km grid #242. RAP fields are also available for the larger North American domain on 32 km grid #221. A limited set of fields from the RAP runs (and other NCEP models) can also be viewed at **http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller.** (EMC&NCO)

Verification of RAP

ESRL's verification of the RAP is available from **http://ruc.noaa.gov/stats**. NCEP maintained its capability and provided access to routine verifications of the operational RAP analyses and forecasts. These include grid-to-station verifications versus rawinsonde, surface, aircraft, Profiler, and VAD data computed periodically at NCEP and accessible via NCEP's Mesoscale Modeling Branch website: **http://www.emc.ncep.noaa.gov/mmb/research/meso.verf.html** .

Deliverables	**Delivery Schedule**
Task 1 – Improve turbulence guidance from NWP forecasts	
a. Finalize code for RAPv2 for implementation at NCEP (ESRL, NCEP) • Vigorous effort leading complete package with extensive improvements, summary at: **http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2013.pdf**	Mar 2013 **COMPLETE**
b. Complete the testing of the 40/13 km dual-resolution hybrid DA system for RAP with 3-hourly cycles with conventional data (GSD, CAPS) • Initial work completed by CAPS, testing of further enhancements to system. GSD testing and inclusion in RAPv2 of hybrid system with full observational data, using GFS ensemble data. Milestone exceed.	Mar 2013 **COMPLETE**
d. Report on early version of RAPv3 primary cycle at GSD with physics enhancements for initialization of the HRRR. (ESRL)	Dec 2013
e. Report on the optimal configurations for including satellite data in the 40/13 km dual-resolution hybrid system to ensure overall positive impacts of the data (NCEP, ESRL)	Dec 2013

Deliverables	Delivery Schedule
f. Finalize RAP version to initialize experimental HRRR for 2014 real-time use toward operational HRRR (ESRL)	Mar 2014
g. Deliver progress report on development of NARRE (NCEP, ESRL)	Mar 2014
h. Deliver progress report on ensemble/hybrid data assimilation for use in NARRE (ESRL, NCEP)	Mar 2014
i. Subject to NCEP Directors' approval, upgrades to observation processing &/or quality control and/or GSI and/or NMMB systems become Operational at NCEP. (NCEP)	Mar 2014
j. Incorporate physics and dynamics improvements from the user community, GSD, and NCEP into WRF for use in the Rapid Refresh system. (NCAR-MMM)	Mar 2014

Task 2: Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

GSD

An intensive work effort during the quarter has focused on testing and evaluating numerous enhancements to GSD RAPv2 / HRRR data assimilation and modeling systems, both in retrospective experiments and in merged real-time evaluations. Numerous obstacles, both scientific and technical (computer related) have been overcome and an extensive package of enhancements to both RAPv2 and HRRR model and data assimilation systems is successfully running and yielding significant forecast improvements from both RAP and HRRR for convection and most other forecast parameters.

A complete listing of the system enhancements can be found at:
http://ruc.noaa.gov/pdf/ESRLRAPHRRRchanges2013.pdf

Key systems enhancements include:

RAPv2 MODEL
-- updated from WRF-ARW version 3.3.1 base to version 3.4.1 base
-- upgraded PBL parameterization from MYJ to enhanced MYNN
-- Improved Smirnova LSM with 9 levels and improved roughness length specification
-- Other small adjustments to RAP physics modules and radar reflectivity diagnostic code

RAPv2 DATA ASSIMILATION
-- upgraded GSI from standard 3DVAR formulation to EnKF-hybrid assimilation using GFS 80-member ensemble
-- improved specification / removal of precipitation hydrometeors including number concentration for consistency with Thompson microphysics scheme
-- improved soil temperature and moisture adjustment to increase magnitude and make it symmetric for warm/drying and cooling/moistening
-- improved snow cycling -- added snow building capability, removed temperature dependence for snow trimming
-- improved cloud building from METARs for cases with nearby fractional cloud coverage

HRRR MODEL
-- updated from WRF-ARW version 3.3.1 base to version 3.4.1 base
-- upgraded PBL parameterization from MYJ to enhanced MYNN
-- upgraded shortwave radiation scheme from Dudhia to Goddard
-- Improved Smirnova LSM with 9 layers and improved roughness length specification

-- Other small adjustments to RAP physics modules and radar reflectivity diagnostic code

HRRR DATA ASSIMILATION
-- Added 1-h pre-forecast spin-up period including 4 applications of DFI reflectivity-based latent heating
-- Added application of GSI analysis on HRRR domain following 1-h pre-forecast cycle to incorporate latest observations

These changes have added important new capabilities to the RAPv2/HRRR system and have addressed a wide range of shortcomings. Some specific areas of improvement for some of the most key changes include:

1. RAPv2 EnKF hybrid assimilation – significant improvement in RAP upper-level temperature, relative humidity, and wind fields. This improved mesoscale environment translates to improved mesoscale location / structure of HRRR convective systems.

2. MYNN PBL scheme in RAP and HRRR – significant improvement in PBL structure, especially winds, also reduced bias in near-surface temperature and dewpoint fields.

3. New 9-layer LSM, enhanced soil adjustment and snow building / trimming – reduced near-surface temperature and dewpoint errors, especially improved diurnal pattern to biases.

4. New HRRR data assimilation package (1-h pre-forecast cycle with 15-min latent heating, GSI application) – elimination of HRRR precipitation spin-up issue and improved reflectivity verification through 4-6 hours in HRRR forecasts

Testing, evaluating, optimizing, and incorporating all of these changes into the GSD real-time experimental RAPv2/HRRR system has required an intensive research effort involving numerous retrospective and real-time parallel cycled experiments to evaluate all the changes individually, then in combination with other enhancements (including evaluating impact of RAPv2 changes on both the RAPv2 and the HRRR).

A final crucial piece was transferring the changes form the RAPv2/HRRR development system on Zeus to jet (and resolving a number of computer-related issues) and then optimizing the system to minimize both core usage and wall clock execution time. With regard to wall clock execution time, a system with significantly greater capability (hybrid DA for RAPv2, 1-h pre-forecast and GSI application for HRRR) is now completing in less time than the previous RAPv2/HRRR system and using only ~250 more cores.

Recent results (see figs. below) from the enhanced real-time experimental GSD RAPv2/HRRR system have been impressive. Sample HRRR reflectivity plots reveal the ability of the system to capture both large-scale and small-scale convective details at moderate lead times. Longer range forecast (through 15 h, not shown) have shown similarly impressive forecast skill. Very short range forecast (0-2 h) have revealed virtually no HRRR model spin-up issues (due to the 1-h pre-forecast cycle) and impressive accuracy for small-scale convective features.

GSD has had discussions with the NCAR WRF developers concerning small-scale oscillations in low-level fields under conditions of steep terrain slope and strong surface wind when the 6th order diffusion is turned on. This is specifically a HRRR issue occurring only under a circumscribed combination of terrain slope and strong low-level wind, and does not affect the RAP. Until a definitive solution becomes available, the HRRR will be run without 6th order diffusion.

Work in two other important areas is ongoing. First, a key milestone was achieved on Feb. 14, when real-time transfer of HRRR grib2 output files from JET to NCEP Central Operations (NCO) commenced, with dissemination via their ftp server commencing shortly thereafter. Second GSD scientists and IT personnel continue to work with NCEP IT specialists to complete key file transfer links that would enable complete independence between the JET and ZEUS real-time experimental RAP/HRRR systems. This work involves obtaining independent feeds of key observations and parent model grids to the JET and ZEUS machines and obtaining independent transfer and dissemination of the output grids from the machines.

Work also continues in coordination with EMC and NSSL colleagues on further developing and evaluating HRRR-based Real-Time Mesoscale Analysis (RTMA) and Rapidly Updated Analysis (RUA) products. Good progress

has been made for both of these, with prototype hourly updated test systems running in real-time over the past few months (though temporarily suspended to allow for more intensive evaluation RAP/HRRR changes. A report summarizes this work can be found at:

http://ruc.noaa.gov/pdf/GSD_RTMA_report_March15_2013.pdf

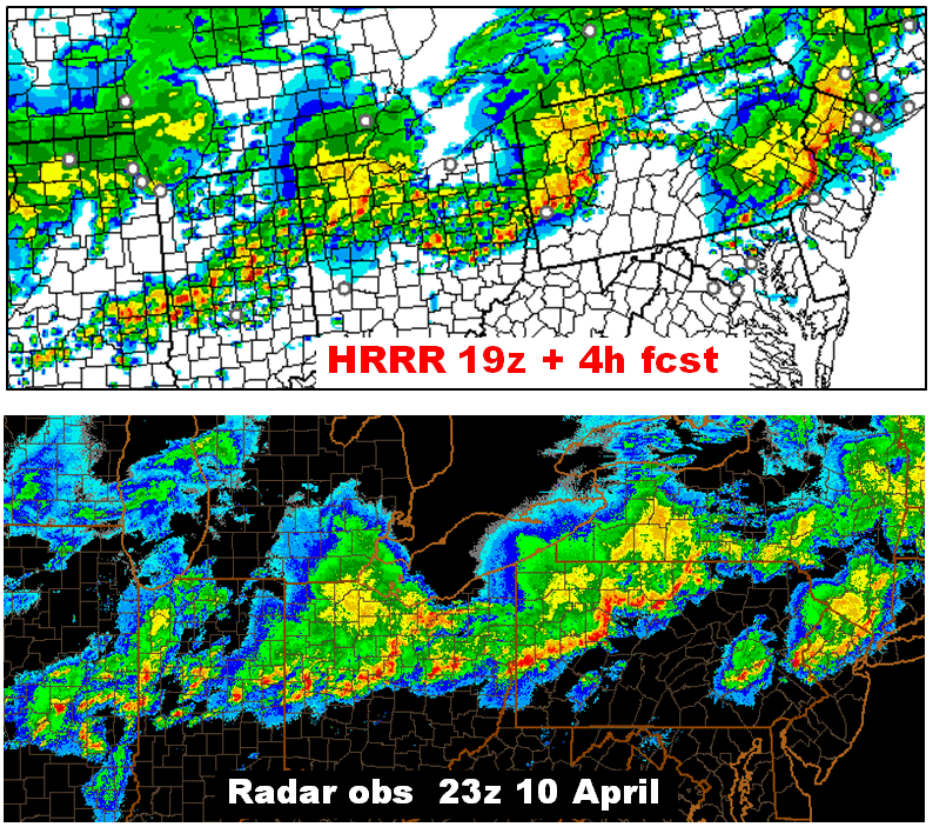

Fig. 2 4-h HRRR forecast and observed reflectivity valid 2300 UTC 10 April 2013

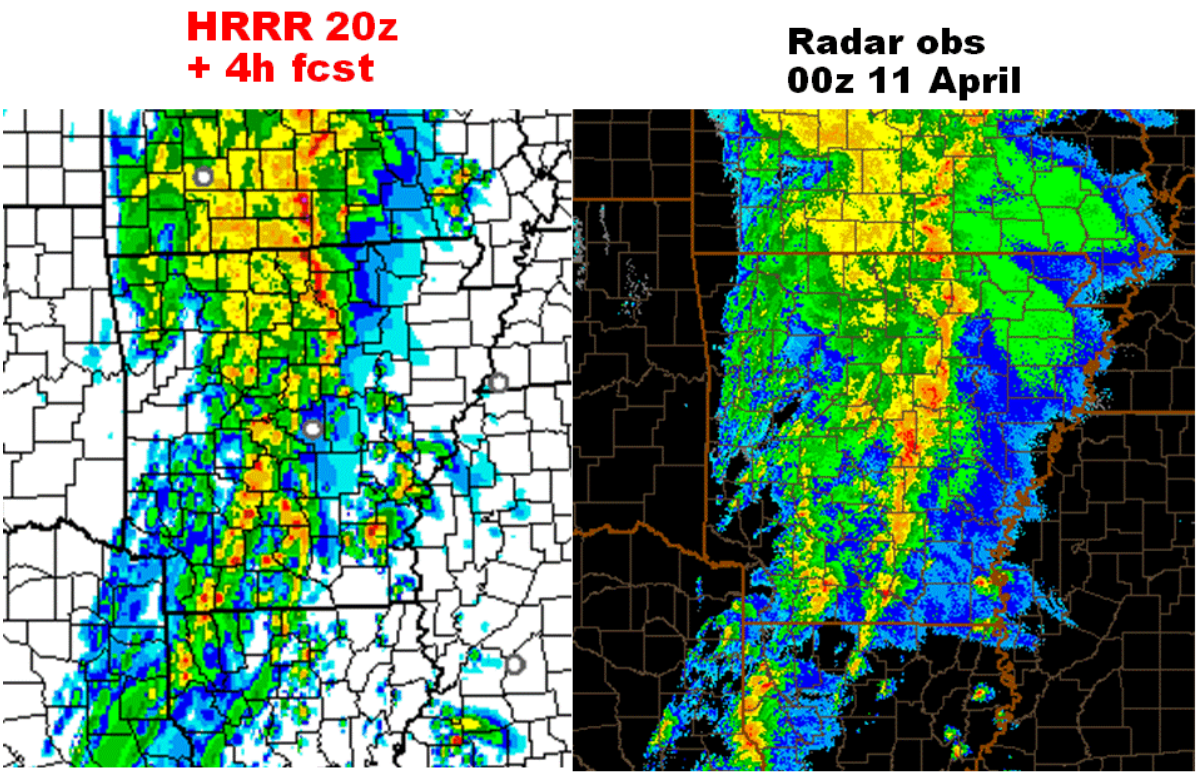

Fig. 3 4-h HRRR forecast and observed reflectivity valid 0000 UTC 11 April 2013

NCEP

EMC ran a timing test of the HRRR code on WCOSS in February. (Curtis Alexander from ESRL also first performed the same test.) This was a preliminary test to obtain an initial sense of run time and resources required to run the system to assist with future efforts to implement the HRRR. (Geoff Manikin)
NCEP EMC & NCO conducted a planning exercise of what the modeling suite might look like on WCOSS Phase 1 and Phase 2. The size of the latter would be enhanced by the Sandy Supplemental funds. This plan incorporated ESRL/GSD along with all other contributors to the NCEP Production suite. NWS Director was briefed 28 March. While tentative, these plans called for HRRR implementation on Phase 1 and a HRRR Ensemble (HRRRE), combining multiple runs with configurations of both WRF-ARW and NMMB, on Phase 2. A sizable bank of computing was dedicated on Phase 2 to advanced data assimilation for the convective allowing scales of the HRRRE, likely involving a 4-dimensional version of the current GSI-hybrid-EnKF.

Deliverables	**Delivery Schedule**
Task 2 – Improve Quality of Convective Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE	
a. Report on initial tests of 3-km 15-min RTMA cloud / surface analysis for use in frontal diagnostics, CI assessment and other near-surface assessments (ESRL, NCEP) • *Good progress toward 3km RTMA and RUA surface and cloud analyses* • *Successful initial tests summarized in report:*	Feb 2013 COMPLETE

Deliverables	Delivery Schedule
http://ruc.noaa.gov/pdf/GSD_RTMA_report.pdf	
b. Incorporate all assimilation and model changes that affect the HRRR into a frozen version of HRRR (and parent Rapid Refresh) for 2013 real-time use (ESRL) • *Extensive set of enhancements in place and running in real-time experimental GSD RAPv2 / HRRR system*	Mar 2013 **COMPLETE**
c. Provide preliminary 15-min RTMA surface analyses as experimental improved basis for frontal diagnostics and other diagnostics from surface analyses (ESRL, NCEP)	Apr 2013
d. Report on computing resource status on NCEP Central Computing System, NOAA R&D Site A and NOAA R&D Site B with regards to possible implementation of HRRR (NCEP, ESRL)	Jun 2013
e. Complete FY13 internal assessment with revised 3-km HRRR running every hour (ESRL)	Sept 2013
f. Provide revised 15-min RTMA surface analyses as primary basis for frontal diagnostics and other diagnostics from surface analyses for real-time use in 2014 (ESRL, NCEP)	Feb 2014
g. Finalize all changes to the HRRR for real-time use in 2014 (ESRL)	Mar 2014

Task 3: Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE

GSD

Summary: Extensive testing and evaluation of physics options for RAPv2 continuing through January and February into March led to the late March decision on the following physics configuration for RAPv2, to be used within the WRFv3.4.1 code:

- New 9-level configuration of the RUC land-surface model (RUC LSM)
- Mellor-Yamada-Nakanishi-Niino (MYNN) planetary-boundary- and surface-layer scheme in place of the current Mellor-Yamada-Janjic (MYJ) scheme.
- Continue to use of the Grell G3 scheme from WRFv3.2.1.
- Continue to use the Goddard short-wave and RRTM long-wave radiation schemes.
- Use WRFv3.4.1 version of the Thompson microphysics.

As a result of the successful testing of major revisions to the RUC LSM coupled with enhancements to the land-surface fields used by the LSM (see MDE-FY13-Q1 report), we introduced the new 9-level configuration into all the GSD RAP-development cycles in February, and during March into the RAP-primary that drives the HRRR. The increased resolution improves 2-m temperature forecasts during the evening transition without leading to cold biases at other times of the day or in winter conditions of snow cover and reduced insolation. Further, the 10-m wind performance has been improved by the modifications to land use and land-surface properties discussed in the FY13-Q1 report.

The concerted effort by Tanya Smirnova and Joe Olson in December 2012 to find and correct the cause of the excessive occurrence of nighttime fog over snow-covered areas kept the MYNN PBL and surface layer as a

strong candidate to replace the MYJ because of its overall substantially improved wind forecasts. During the January – March period intensive testing of further modifications to overcome a daytime dry bias and other issues continued, with emphasis on formulation of the roughness length for heat, and entrainment at the top of the daytime mixed layer through modification of the mixing-length formulation. By late March a version that performed equivalently or better than MYJ for temperature and moisture had emerged. These MYNN modifications go beyond the most recent v3.4.1 WRF release; some will be included as part of the WRFv3.5 release scheduled for April 2013.

Extensive testing of the new Grell-Freitas (GF) convective scheme with the shallow convection and radiation feedback options turned on continued through much of the quarter. A couple of bug-fixes to the scheme that improve conservation and consistency properties were introduced in February, requiring some retesting for confirmation of earlier favorable results with this scheme relative to the v3.2.1 version of the Grell G3 scheme currently in RAPv2. Finally, despite considerable effort to improve RAP precipitation forecasts using GF (generally well-placed but insufficient precipitation), extensive comparison of predictions of wind, temperature, and relative humidity as well as precipitation argued for keeping the present WRFv3.2.1 G3 scheme rather than replacing it with the WRFv3.5 version of GF.

The use of WRFv3.4.1 by default incorporates the NCAR (Greg Thompson) fix to allow attenuation of incoming solar radiation by clouds in the Goddard short-wave radiation scheme. So this will be part of the RAP physics configuration used with the RAP-primary that will feed the HRRR for this summer's convection exercise.

In a related effort, David Dowell and Curtis Alexander introduced code into the GSI cloud analysis to ensure that the conversion between reflectivity and mixing ratios of rain, snow and graupel is reversible and consistent with the v3.4.1 Thompson scheme.

NCEP

EMC ran a timing test of the HRRR code on WCOSS in February. (Curtis Alexander from ESRL also first performed the same test.) This was a preliminary test to obtain an initial sense of run time and resources required to run the system to assist with future efforts to implement the HRRR. (Geoff Manikin)

Brad Ferrier provided information to Greg Thompson (NCAR) regarding the NMMB model code to help him in integrating his microphysics scheme into the model. Eugene Mirvis helped Laurie Carson (DTC) port the NMMB code that NCEP runs on Zeus to NCAR's Yellowstone computer, where Greg Thompson was able to run a 4-hr test forecast for a 1 Feb 2011 case. (Brad Ferrier) Planning continues to assist Greg Thompson with his suggestions to do radiation-microphysics coupling via working more directly with NCEP's RRTM expert Yu-Tai Hou and others at EMC. His suggested changes do not involve the aerosol work already done in his WRF-ARW version, however. Rather, his changes would bypass the internal assumptions of droplet and ice sizes assumed within RRTM and utilize directly computed water/ice radii from the Thompson microphysics scheme instead. Since the versions of RRTM used at NCEP and within WRF have diverged, there is some risk this will be more involved than currently envisioned.

NCAR/RAL

CURRENT EFFORTS: During the month of March, NCAR-RAL nearly completed the effort of enabling and testing the new aerosol-aware Thompson microphysics scheme. Initial testing reveals successful behavior of conditions with greater or fewer aerosols acting as CCN and ice nuclei. A large-scale, high-resolution WRF simulation lasting 48 hours was performed with aerosol conditions similar to present day levels using the GOCART climatology data specifically constructed for these test purposes. Then, a sensitivity experiment was performed in which these aerosols were purposefully increased substantially to evaluate the resulting effects on clouds and precipitation. Preliminary indications are all positive with regard to expected changes to clouds, however additional and more detailed analysis of specific cloud changes are ongoing. NCAR-RAL briefed NOAA-GSD colleagues on these results.

FUTURE EFFORTS: A remaining step for this task is to transfer the new aerosol-aware code to NOAA-GSD and then begin work on more explicit coupling with their existing WRF-Chem model configuration.

PROBLEMS/ISSUES ENCOUNTERED: Due to very uncertain funding situation for remainder FY2013 (as of this writing April 2013), we are not sure when the transfer of codes and additional work will be performed by NCAR-RAL.

NCAR/MMM

Deliver a WRF Users' Workshop and WRF Tutorial for the User Community

NCAR conducted a WRF tutorial at its Foothills Lab January 28–February 5, 2013. This included a WRF tutorial and a MET (Model Evaluation Tools) tutorial. Approximately 60 participants attended the tutorial. The tutorial is further described at: **http://www.mmm.ucar.edu/events/tutorial_131/index.php.**

NCAR began putting together the next WRF workshop, the 14th WRF Users' Workshop. This will be at NCAR's Center Green facility in Boulder on June 24–28. In addition to three days of WRF-related presentations and discussions, it will feature a half-day of lectures on fundamentals of WRF physics—radiation. The final day will feature tutorial-type sessions on packages such as WRF-Hydro, NCL, and VAPOR.

PLANNED EFFORTS: NCAR will continue to prepare the 14th WRF Users' Workshop. It will also begin to set up the next WRF tutorial, which will be at NCAR in July.

UPDATES TO SCHEDULE: NONE

Incorporate Physics and Dynamics Improvements into WRF

NCAR and the WRF Release Committee prepared the next major release, WRF Version 3.5. This release will be in April 2013, and release details may be found at: **http://www.wrf-model.org/release.php**. Candidate features include software framework improvements, a WRF hydrology model, new physics options, new observation types for WRFDA, and WRF-Chem additions.

Two friendly-user releases were issued, with feedback received. These distributions allow the code to be tested and problems to be identified and corrected before the general release.

Jimy Dudhia of NCAR/MMM contributed to the preparations for WRF V3.5 release. He incorporated bugfixes for the CLM4 LSM package and WSM6 microphysics. He also contributed to changes for CAM physics to reduce memory requirements (includes microphysics, cumulus, shallow cumulus, and land surface physics).

Dudhia spoke on physics plans for WRF-Solar, a subset of WRF code tuned for solar energy forecasting. The physics targeted are cloud scheme and radiation improvements, and the changes would benefit WRF as a whole.

Dudhia worked with Stephanie Evan (NOAA) on WSM5 microphysics in upper tropospheric applications. The region studied has been the tropical tropopause, and they worked on correction of biases. Dudhia also worked with Jim Doyle (NRL) on a schematic of a new physics driver for general use in NUOPC models as part of the Physics Interoperability Group.

PLANNED EFFORTS: The development and incorporation of new physics and dynamics for WRF for the RAP will continue into FY13Q3.

UPDATES TO SCHEDULE: NONE

Task 3 – Improve Quality of Icing Weather Forecasts from RAP, HRRR, NAM, NAM-nests and, eventually, NARRE and HRRRE	**Delivery Schedule**
a. Complete initial evaluation of aerosol-aware microphysics in RAP real-time cycling at GSD for its suitability as part of the RAPv3 prototype for 2014 NCEP implementation (NCAR-RAL, ESRL)	Delay until funding restored to

	NCAR
b. Final model physics code transfer complete to EMC for Rapid Refresh 2 upgrade change package to be implemented at NCEP by spring 2014 (ESRL, NCEP) • Freeze of model physics code for March 2013 version of RAP at ESRL allows this milestone to be met.	Mar 2013 **COMPLETE**
c. Pending NCEP computer readiness and EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh v2 software to NCO (NCEP, ESRL)	May 2013
d. Transfer upgraded coupled aerosol-microphysics scheme into a test version of HRRR (NCAR-MMM, ESRL)	Dec 2013
f. Finalize microphysics changes and other physics changes to improve icing forecasts for ESRL version of RAP and HRRR for 2014 real-time use (ESRL)	Mar 2014
g. Report summary of icing probability skill measures by quarter for the year. (NCEP)	Mar 2014

Task 4: Develop convection-ATM-specific improvements for guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA

Current:
Extensive package of enhancements to GSD RAPv2 / HRRR system completed and yielding impressive forecast skill. This package is the culmination of exhaustive testing and evaluation of candidate enhancements individually and in combination. Enhancements include:

RAPv2 MODEL
-- updated from WRF-ARW version 3.3.1 base to version 3.4.1 base
-- upgraded PBL parameterization from MYJ to enhanced MYNN
-- Improved Smirnova LSM with 9 layers and improved roughness length specification
-- Other small adjustments to RAP physics modules and radar reflectivity diagnostic code

RAPv2 DATA ASSIMILATION
-- upgraded GSI from standard 3DVAR formulation to EnKF-hybrid assimilation using GFS 80-member ensemble
-- improved specification / removal of precipitation hydrometeors including number concentration for consistency with Thompson microphysics scheme
-- improved soil temperature and moisture adjustment to increase magnitude and make it symmetric for warm/drying and cooling/moistening
-- improved snow cycling -- added snow building capability, removed temperature dependence for snow trimming
-- improved cloud building from METARs for cases with nearby fractional cloud coverage

HRRR MODEL
-- updated from WRF-ARW version 3.3.1 base to version 3.4.1 base
-- upgraded PBL parameterization from MYJ to enhanced MYNN
-- upgraded shortwave radiation scheme from Dudhia to Goddard
-- Improved Smirnova LSM with 9 layers and improved roughness length specification
-- Other small adjustments to RAP physics modules and radar reflectivity diagnostic code

HRRR DATA ASSIMILATION

-- Added 1-h pre-forecast spin-up period including 4 applications of DFI reflectivity-based latent heating
-- Added application of GSI analysis on HRRR domain following 1-h pre-forecast cycle to incorporate latest observations

Planned:
With completion of the development cycle this quarter, work will focus on further real-time (warm season) documentation of improvements and optimization of on-demand Zeus back-up system.

Task 4 – Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2013 real-time use

Current:
Ming Hu, David Dowell and Tanya Smirnova have developed an improved retrieval in GSI of rain and snow hydrometeors from radar reflectivity observations that results in a reversible diagnostic of model reflectivity in WRF from the hydrometeors that both matches the observed reflectivity and is consistent with the model microphysics scheme (Thompson) used in the RAP and HRRR. This work has led to an improved analysis of radar reflectivity, including echo tops, and these initial conditions should translate into improved reflectivity and echo top forecasts from the RAP and HRRR. Initial results look good except for a possible minor issue with the some 0-h retrieved reflectivity values being too high in intense convection.

Planned:
Further evaluation of new microphysics / reflectivity conversion including assessment and resolution of the 0-h high reflectivity value issue.

Task 4 – Assess HRRR reliability and provide monthly reporting

Current:

Work continues towards an independent 2-computer solution for HRRR model forecast production and distribution for use in CoSPA. RAP and HRRR on Zeus are being restored to the back-up capacity (matched system to jet). Significant recent progress has been made by GSD IT personnel to enable testing of HRRR file transfer directly from Zeus to GSD machines (bypassing Jet). Investigation is ongoing to determine file transfer speed.

HRRR Reliability for 0-8 Hour VIL/Echo Tops for March 2013

Jet
All runs: 84.1%
3 or more consecutive missed runs: 92.2% (most meaningful for CoSPA)
6 or more consecutive missed runs: 95.0%
9 outages of at least 3 hrs or longer
5 outages of at least 6 hrs or longer

Zeus
*** NOTE: during March Zeus was used extensively for HRRR development testing and not as a backup capacity. The HRRR-dev on Zeus is now being restored to its backup capacity ***
All runs: 46.8%
3 or more consecutive missed runs: 30.9% (most meaningful for CoSPA)
6 or more consecutive missed runs: 33.6%
9 outages of at least 3 hrs or longer
5 outages of at least 6 hrs or longer

Combined (Jet or Zeus)
*** Not computed, given use of Zeus for HRRR development***

Planned:
Work will be focused on distribution of HRRR model forecast data to ESRL/GSD from Zeus without using Jet resources, allowing for a completely redundant real-time experimental HRRR system. Requests for dedicated computer reservations on Zeus, to further increase the reliability of the HRRR, will be submitted.

Task 4 – Complete implementation of refined SatCast assimilation for HRRR for real-time use in 2014

Current:
Tracy Smith ported SatCast assimilation code (previously developed for use with the RUC analysis) from the RUC to the RAP (GSI package). The code ingests SatCast IR cloud-top cooling data and maps it into a local heating function that is applied to the RAP fields in a similar manner to the way the RAP assimilates radar reflectivity data. Using a sample IR cloud-top cooling rate data set from a convectively active period in early July 2012, she completed a preliminary 1-day retrospective experiment (control run without the SatCast data and experiment with the SatCast data). Preliminary results indicate that for a scattered thunderstorm situation over the Southeastern U.S., assimilation of the SatCast IR cooling rates leads to a better short-term prediction of small-scale convective systems. Further work is ongoing.

Interact with CoSPA (or other) program partner labs and the FAA

Current:
CoSPA team telecon and e-mail correspondence has occurred in conjunction with issues related to the HRRR code freeze and the resolution of these issues.

Planned:
The CoSPA demonstration period will begin on 17 April, with ongoing communication amongst the teams (ESRL/GSD, NCAR/RAL, and MIT/LL).

Deliverables	**Delivery Schedule**
Task 4 – Develop convection-ATM-specific improvements to guidance from the HRRR (and later, HRRRE) and interact with CoSPA (or other) program partner labs and the FAA	
Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2013 real-time use (ESRL) • Code for revised echo-top / reflectivity diagnostics with revised microphysics implemented in GSD real-time HRRR.	Mar 2013 **COMPLETE**
Conduct baseline testing of the early 2013 HRRR version (ESRL) • Baseline testing of 2013 HRRR version completed as part of code preparation for freeze. Summary of skill score improvements being prepared.	Mar 2013 **COMPLETE**
Report on evaluation of new microphysics scheme and associated echo-top and reflectivity diagnostics in ESRL/GSD RAP and HRRR (ESRL) • *Preliminary evaluation completed and summarized in report:* **http://ruc.noaa.gov/pdf/GSD_reflectivity_report.pdf**	Mar 2013 **COMPLETE**

Assess HRRR reliability and provide monthly reporting (ESRL)	Apr 2013
Report on evaluation of revised WRFv3.4 microphysics for RAP/HRRR for its effects on echo-top and reflectivity in ESRL RAP/HRRR (ESRL)	Mar 2014
Complete implementation of new microphysics for associated reflectivity echo-top diagnostics for 2014 real-time use of HRRR (ESRL)	Mar 2014
Complete implementation of refined SatCast assimilation for HRRR for real-time use in 2014 (ESRL)	Mar 2014
Report on 2014 baseline testing of the HRRR (ESRL)	Mar 2014